A comparison of the position of elite and non-elite riders during competitive show jumping

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Abstract

The purpose of this study was to compare the jumping positions of elite riders (within the top 150 of the British Showjumping rankings) with non-elites (unranked). Video footage of 10 elite and 10 non–elite riders jumping a one stride double combination (a vertical followed by a square oxer) within a 1.20 m competition was analysed. Four angles were measured: the angle between the trunk and the vertical ($TRUNK_{vert}$), the hip angle (HIP), the angle of the thigh to the horizontal ($THIGH_{horiz}$) and the angle of the lower leg to the horizontal ($LOWER\ LEG_{horiz}$). Differences in the angles at five points throughout the double combination and the changes in angles between points were compared using Mann-Whitney U tests. The effect of fence (vertical versus oxer) within groups (elite and non-elite) was also compared. The level of significance was set at $p<0.05$. HIP angle was significantly smaller on approach to the vertical ($P=0.019$) and significantly greater when approaching the oxer ($P=0.001$) for elite riders compared to non-elites. During approach to the oxer compared to the vertical elites had a greater HIP angle ($P=0.007$), whereas non-elites had smaller HIP ($P=0.005$) and $THIGH_{horiz}$ ($P=0.005$) angles. During suspension, non-elite riders had a greater HIP ($P=0.01$) over the vertical and smaller $LOWER\ LEG_{horiz}$ angle over the oxer ($P=0.028$) than elite riders. There were significant differences in change in HIP, $THIGH_{horiz}$ and $LOWER\ LEG_{horiz}$ angles between elite and non-elite riders between approach to and suspension over the oxer ($P=0.007$). During suspension, only elite riders showed an effect of fence with a greater HIP angle ($P=0.005$) and smaller $TRUNK_{vert}$ angle ($P=0.013$) over the oxer. Key differences in angles and change in angles exist between elite and non-elite riders. This information is useful in characterising elite rider position and identifying areas of interest for future study.

Introduction

The study of the rider's physiology and biomechanics has received increasing attention in research studies within the last fifteen years. Rider biomechanics have been studied in walk, trot and canter with differences between inexperienced and experienced riders described (Lagarde *et al.,* 2005; Lovett *et al.*, 2005; Peham *et al.*, 2001; Schils *et al.*, 1993; Terada 2000; Terada *et al.,* 2004). As with all other equestrian disciplines, success in show jumping involves both human and equine athlete working in partnership. Many studies have focussed on the desirable biomechanics of the show jumping horse (Barrey and Galloux 1997; Deuel and Park, 1991; Santamaria *et al*., 2004, 2005) but fewer have considered the biomechanics of the rider (Patterson *et al*., 2010; Powers and Harrison 2004). The study of rider biomechanics is worthwhile not only in the interests of performance enhancement, but also in reducing risk of rider injury caused by falls. Horse riding is a dangerous sport and jumping is the most dangerous horse riding activity (Silver, 2002). O'Farrell *et al.* (1997) found that seven out of nine major pelvic injuries caused during equestrian sport occurred whilst jumping. Injury is not merely a 'novice' rider problem; more advanced exercises are connected with a greater risk of injury; with the highest injury rates among riders competing at the highest levels (Paix, 1999).

Powers and Kavanagh (2005) compared the jumping kinematics of ten horses when jumped over a 1.05 m vertical fence by both an experienced and an inexperienced rider. They found no difference in the jumping kinematics of the horses when ridden by the two different riders but noted that the experienced rider was 'more balanced and in control of the horse'. Patterson *et al*. (2010) found clear differences between experienced and novice riders jumping a 1.20 m vertical fence in terms of accelerations of body segments measured using inertial motion sensors. These authors found that the experienced riders had less total head accelerations during the jump than novice riders. Novice riders had higher peak arm and leg accelerations on landing, suggesting that these riders were less able to maintain their balance on landing.

It is widely known that analysis of technique is essential to develop an understanding of how a sport's skill is performed. In turn this understanding can improve the coaching and ultimately the performance of that skill. Although many terms are used to describe such studies they all fall within the umbrella definition of 'technique analysis', defined by Lees (2002). A commonly recognised path to progressing technique analysis is to describe the desired technique, as modelled by elite performers, and then use this to identify the variables that characterise technique. Research in the horse-rider interaction within competitive equestrian sport is in its infancy, and therefore equestrian sports' technique analysis is still at the stage of determining the variables that should be described and studied further to allow technique to be understood. In order to improve rider skill in show jumping, the first step is to characterise the technique of elite performers and to describe how their technique differs from non-elites. The primary aim of this study was to compare the jumping positions of elite and non-elite riders at five points throughout negotiation of a double combination and the changes in elite and non-elite rider position between the five points. A further aim was to analyse the effect of the fence type (vertical versus square oxer) on the position of elite and non-elite riders.

Materials and Methods

Rider positions were analysed using video footage from a 1.20 m showjumping competition (Bronze Tour) at the Hartpury Showjumping Spectacular 2010, a competition in which both professionals and amateurs took part. The protocol for this study was approved by Hartpury College Ethics Committee.

Participants: All riders competing in the competition (n= 77) had given informed consent for the video recording to occur and understood that anonymous analyses would be performed. Only footage from riders achieving clear rounds (35/77) were considered for inclusion in the sample to reduce the possibility of unsuccessful jumping efforts negatively affecting results by increasing variability within the samples. In this way this study of technique analysis aims to identify the variables that characterise rider position during a successful jumping effort. The recordings from the ten riders with the highest positions in the British Showjumping rankings (all within the top 150) were selected to form the 'elite' sample. British Showjumping (BS) ranks the top 250 British riders that have won points at international level at 1.50m and above, and describes those outside this ranking system as amateurs. Ten recordings were randomly selected from the remaining 25 clear rounds using a random number generator from those riders who were unranked amateurs to form the 'non-elite' sample.

Data Collection: Both parts of a one stride (7.80 m) double combination (consisting of a vertical followed by a square oxer) were studied. The double formed element 9 of a course of 12, consisting of 16 jumping efforts in total. The double was positioned against the long side of a 70 m x 40 m all weather arena and was approached off the left lead. Video recording at 50 fps was obtained using a tripod mounted video camera (Panasonic HC-V130EB-K Full HD Camcorder) situated on the opposite side of the arena with the camera directed at the midpoint of the combination. A panning technique was used to capture all events from the approach stride of the first element to the jump suspension of the second element (i.e. vertical approach stride, vertical jump stride, intermediate stride, oxer jump stride) (Clayton 1989). The field of view was 8.5 m x 4.5 m and horses jumped from right to left. For both fences, a frame corresponding to 'approach' and 'suspension' were selected for analysis; with 'approach' corresponding to a frame in which both fore hooves were in contact with the ground during the stride immediately preceding take off (approach stride A1 as defined by Clayton and Barlow (1991) for the vertical and intermediate 1 for the oxer (Clayton 1989)) and 'suspension' corresponding to the frame exhibiting peak flexion of the forelimbs whilst in jump suspension over the fence (Clayton 1989). For the vertical fence only, the rider's position was also quantified during the 'landing' phase of the jump stride corresponding to the first frame in which both forelimbs were in full contact with the ground. It was not possible to capture landing from the oxer as another fence on the course prevented a clear view. Measurements for a total of five stages of jumping the double combination were described. The angle measurement tool within Dartfish Team Pro 5.5™ (Fribourg, Switzerland) software was used to determine the angles.

The following angles were measured as depicted in Figure 1.

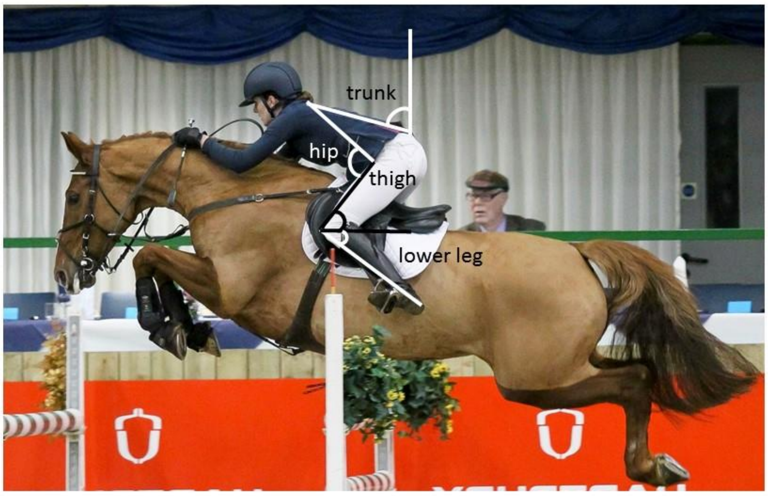

Figure 1: Angles chosen for analysis shown here in ‘suspension’.

The TRUNK$_{vert}$ angle was given by the intersection of two lines, one drawn vertically from the most posterior point of the rider’s seat and another drawn from the most posterior point of the rider’s seat to the point of the shoulder. The HIP angle was formed by lines drawn from the point of the shoulder to the most anterior point of the uppermost thigh and on to the most anterior point of the knee. The THIGH$_{horiz}$ was the angle formed by a line between the anterior point of the uppermost thigh and the most anterior point of the knee with the horizontal. The LOWER LEG$_{horiz}$ was the angle formed by a line from the most posterior point of the rider’s boot (heel) to the most anterior point of the knee with the horizontal. These points were all chosen because they were easily identifiable from the video and repeatable within ± 2° (the within subject standard deviation based on repeats on ten measurements). Changes in body position between each stage of the double combination and the preceding stage were also calculated e.g. TRUNK$_{vert}$ (approach vertical) – TRUNK$_{vert}$ (suspension vertical) in order to obtain a value for the change in body segment angle (range of movement) between each stage for both elite and non-elite riders.

Data analysis: Given the relatively small sample size a non-parametric approach was taken to all analyses as recommended for samples of 30 and below by Razali and Wah (2011). Angles from elite and non-elite riders for the approach, flight and landing phases were compared using a series of Mann-Whitney U tests. The effect of fence type on angles within elite and non-elite riders were also compared using Mann-Whitney U tests. The change in angles between each consecutive stage of the double combination (approach to flight, flight to landing) was also calculated and compared between elite and non-elite riders. Statistical analyses were carried out using the Statistical Package for Social Scientists (SPSS) version 22.0 (SPSS Inc., Chicago, IL., USA). The level of significance used was p=0.05.

Results

Comparison of position of elite and non-elite riders:

Rider angles over the vertical and oxer are shown in Table 1. Between the approach and suspension phase of each fence, both groups of riders increased $TRUNK_{vert}$. During the suspension phase all riders decreased the HIP angle and then increased it on landing to a position larger than that on approach. The $THIGH_{horiz}$ angle became smaller during suspension over the vertical than approach, increasing on landing. Elites had a significantly smaller HIP angle at both the approach (Z = -2.343, P=0.019) and suspension (Z = -2.572, P=0.01) phase of the vertical fence but there was no significant difference on landing between the two groups (P<0.05).

Table 1. A comparison of elite and non-elite rider position (median angles in degrees (lower quartile-upper quartile)) over a vertical and square oxer fence.

	VERTICAL				OXER			
	$TRUNK_{vert}$	HIP	$THIGH_{horiz}$	LOWER LEG_{horiz}	$TRUNK_{vert}$	HIP	$THIGH_{horiz}$	LOWER LEG_{horiz}
APPROACH								
Elite	15 (11–15)	117[a,b] (113–122)	55 (52–63)	65 (63–73)	12 (7–14)	131[a,b] (127–135)	41 (37–47)	65 (63–67)
Non-elite	13 (7–15)	125[a,b] (122–128)	46[b] (41–57)	70 (67 – 73)	14 (11-20)	113[a,b] (109–117)	40[b] (37–43)	67 (63–73)
SUSPENSION								
Elite	56[b] (50–62)	80[a,b] (72–85)	49 (44–53)	65 (63 –67)	48[b] (42–51)	88[b] (86–89)	40 (37–50)	67[a] (63–74)
Non-elite	46 (37–54)	93[a] (84–97)	41 (32–51)	58 (47– 68)	63 (53–74)	69 (62–83)	37 (36–40)	60[a] (52–62)
LANDING								
Elite	23 (20–26)	135 (132–139)	71 (68–74)	66 (63–68)	na	na	na	na
Non-elite	25 (14–35)	129 (120–137)	68 (63–72)	69 (65–79)	na	na	na	na

[a]signifies a statistically significant difference between groups (i.e. between elite and non-elite riders), p<0.05, [b]signifies a significant difference within groups (i.e. between the vertical and the oxer), p<0.05.

A similar pattern was seen for both groups between approach to and suspension over the oxer as with the vertical fence; i.e. $TRUNK_{vert}$ increased and HIP decreased. Elite riders had a significantly greater HIP angle on approach (P=0.001). The LOWER LEG_{horiz} angle of the elites was significantly greater during suspension than the non-elites (P=0.028).

Differences in elite riders jumping the vertical and the oxer:

The HIP angle of the elite riders was significantly greater on both the approach and suspension phase of the oxer compared to the vertical (P=0.007 and P=0.005). The $TRUNK_{vert}$ angle was smaller during suspension over the oxer than the vertical (P=0.013).

Differences in non-elite riders jumping the vertical and the oxer:
The non-elite riders showed a significantly smaller HIP angle (P=0.005) and a smaller $THIGH_{horiz}$ angle (P=0.005) on the approach to the oxer than the vertical. There was no effect of fence type on the non-elite rider position during the suspension phase.

Comparison of change in position between elite and non-elite riders jumping the double combination:
The changes in position between each stage are shown in Table 2. There was a significantly greater change in HIP angle of elite riders between landing from the vertical and approach to the oxer (P=0.002) and a significantly smaller change between the approach and suspension over the oxer (P=0.029). The elite riders increased the HIP angle more on landing and decreased it less over the oxer compared to the non-elite riders.
The elite riders showed a significant difference in change in $THIGH_{horiz}$ between the suspension over and landing from the vertical compared to the non-elites (P=0.043) and between the approach to and suspension over the oxer (P=0.007), with the elite $THIGH_{horiz}$ decreasing in both these stages. There was a significant difference in change of segment angle of LOWER LEG_{horiz} between the approach to and suspension over the oxer (P=0.007) with the elite group exhibiting a significantly greater change.

Table 2: Change in position between each stage of the double combination for elite and non-elite riders (median (lower quartile-upper quartile))

Δ angle (°)		$TRUNK_{vert}$	HIP	$THIGH_{horiz}$	LOWER LEG_{horiz}
Approach - Suspension (vertical)	Elite	-34 (-40 - -29)	36 (31 – 40)	6 (-2 - 18)	11 (-4 - 26)
	Non-elite	-46 (-49 - -35)	39 (35 – 42)	7 (0-15)	-1 (-6 – 10)
Suspension - Landing (vertical)	Elite	20 (11- 34)	-41 (-56 - -35)	-32[a] (-40 - -14)	-4 (-20 – 4)
	Non-elite	30 (18 – 47)	-51 (-66 - -40)	-20[a] (-23 - -8)	-2 (-15 – 5)
Landing - Approach (oxer)	Elite	7 (3 – 17)	22[a] (13 – 31)	32 (25 – 35)	-1 (-10 - 6)
	Non-elite	15 (2 – 25)	0[a] (-13 – 12)	27 (18 – 33)	6 (-3 -18)

Approach - Suspension (oxer)	Elite	-50 (-61 - -31)	38[a] (30 - 51)	-1[a] (-3 – 7)	11[a] (4 – 16)
	Non-elite	-45 (-52 - --41)	51[a] (47 – 56)	-20[a] (-31 - -5)	-2[a] (-4 – 3)

[a]signifies a statistically significant difference between groups (i.e. between elite and non-elite riders), $p<0.05$.

Discussion

Clayton (1989) highlighted the joint angles of the limbs and the inclination of the trunk to the vertical as useful measurements pertaining to the rider position and its likely effect on the jumping horse. Several decades on, differences in kinematics (Schils *et al.* 1993) and electromyographic activity (Terada *et al.* 2000) between experienced and novice riders have been described in certain gaits and over single fences (Patterson *et al.* 2010, Powers and Kavanagh 2005) but to date there have been no studies investigating differences in position between elite and non-elite riders jumping in competition. Hence the primary aim of this study was to compare the jumping positions of elite and non-elite riders throughout the negotiation of a double combination with a view to identifying aspects of interest of elite rider technique for further study. Throughout all of the five stages of the double combination observed, the variability (given by the inter-quartile ranges) of the elite riders' position was lower than the variability of the non-elite riders' which supports the aim of characterising elite rider technique. Low variability in parameters that characterise technique within elite athletes has been recognised in other sports, for example volleyball (Temprado *et al.* 1997).

The competition chosen for study offered an opportunity to observe elite and non-elite riders competing over the same course. All riders selected for study had jumped clear rounds, and therefore both elite and non-elite horse-rider combinations performed objectively to the same level. Previous work by Powers and Kavanagh (2005) found no difference in jumping kinematics when horses were jumped over a single 1.05 m vertical by experienced and inexperienced riders, however the horses used in that study were 'experienced riding school horses and not competition horses' which may have jumped 'successfully and consistently regardless of the rider's movements or instructions'. Whilst our non-elite riders were experienced rather than 'novice', the use of clear rounds only was an attempt to reduce variability in eliminating those riders whose technique adversely affected horse performance to the extent that it resulted in show-jumping penalties.

There were many significant differences in body angles and the change in body angles between elite and non-elite riders relating to HIP, $THIGH_{horiz}$ or LOWER LEG_{horiz} position but it is interesting to note that none of the significant differences related to $TRUNK_{vert}$. At both approach to and suspension over the vertical, the elite riders had a more closed (flexed) HIP angle than the non-elite riders. Between suspension over and landing from the vertical the elite riders significantly altered the $THIGH_{horiz}$ angle (resulting in the thigh becoming more upright) and so at the point of landing from the vertical the HIP angle of the groups was not significantly different due to the changes that had occurred in the elite $THIGH_{horiz}$ angle. Between the landing from the vertical and the approach to the oxer the elites 'closed' the HIP angle significantly more than the non-elites. Between the approach to and suspension over the oxer the non-elites closed their HIP angle significantly more than the elite riders but the actual HIP angle over the oxer did not differ significantly between the groups. The elite riders appear to adapt their position in preparation for take off over the oxer within the intermediate (non-jumping) stride whilst the non-elite riders make a significantly larger change in HIP angle between approach to and suspension over the oxer. A similar pattern was seen in the $THIGH_{horiz}$ angle; in that between approach to and suspension over the oxer, the non-elite riders increased the $THIGH_{horiz}$ angle significantly more than the elite riders. At the point at which the horse is taking off over the oxer, the elite riders are moving less than the non-elite riders. Between landing from the vertical and approach to the oxer, the HIP angle of the non-elite riders does not alter. The elite riders alter their position quicker than the non-elite riders in readiness for the second element. This supports the findings of Lagarde *et al*. (2005) who found that skilled riders had an enhanced ability to anticipate the horse's motion.

The only differences in the LOWER LEG_{horiz} angle between elite and non-elite riders were seen between approach to and suspension over the oxer (see Table 2). Elite riders decrease the LOWER LEG_{horiz} angle significantly more than non-elite riders during this phase but still have a significantly larger (more forward) LOWER LEG_{horiz} angle than non-elites during suspension. Fence type had an influence on HIP angle in both groups of riders. Elite riders adopted a more closed HIP angle on approach to the vertical than the oxer, whilst non-elites had a more open HIP angle on approach to the vertical than the oxer. The difference in HIP angle between the first and second element is therefore completely opposite to that of the elites. $TRUNK_{vert}$ in elites was significantly larger (i.e. more forward) during suspension over the vertical than the oxer. Either these are true differences in rider technique with fence type or they are a consequence of the sequential nature of the jumping efforts. The fact that the two different fence types were studied as part of a combination limits the ability to attribute the differences in rider position entirely to fence type alone and further studies of single fences of different types are warranted to establish if elite riders adapt their technique according to fence type.

In their study of the influences of a rider on the rotation of the horse-rider system during jumping, Powers and Harrison (2004) concluded that the main effect of the rider in controlling rotation of the horse is likely to be determined before the point of take-off. They proposed that this was largely behavioural (a communication effect) and less one of inertia (influenced by rider position) and so concentrating on the rider's position during jumping may not be as important as we might think. Whilst the elite rider may not be able to positively influence the kinematics of the horse, the study of rider position is warranted to ensure poor rider performance does not negatively influence the horse, particularly when faced with multiple fences. If non-elite riders are more likely to lose balance following successive fences their ability to apply the correct 'aids' and exert an appropriate behavioural effect on the horse will be compromised with resulting injury risk (Hall *et al.*, 2009) as well as increasing the risk of rider falls, the most common cause of horse-related injuries (Abu-Zidan and Rao 2003).

Within this study, external validity was critical to ensure that the techniques of the elite riders represented their competition behaviours and were not artefacts of the study's design. It was recognised that by prioritising external validity, potential compromises to internal validity might be experienced (Campbell and Stanley 1966). For example, measurements made within a competition environment preclude the use of anatomical markers and hence reduce the accuracy and repeatability of body segment angle measurements. As the centre of rotation of the hip could not be determined with any degree of accuracy, the method used in this study is a reflection of the degree of movement of the hip joint rather than a true measurement. The panning camera technique used will have introduced a parallax error which may also influence the absolute angles reported, however, the degree of error would be the same for both groups and would not have had a significant influence on the results. No attempt was made to blind the author to the identity of the riders as the elite riders were recognisable and were sufficiently high profile that they could have been identified. However, there was no commentary on the video footage and the two groups were not analysed separately, but mixed according to their running order in the competition. An experimental approach studying riders in training would enable the use of anatomical markers but would be less likely to incorporate the number of ranked riders seen in this study. An experimental approach is also more likely to encourage riders to change their behaviours to conform to a perceived desirable outcome and therefore it is possible that rider positions would not be representative of those in the field.

The results of this study show that the major differences between elite and non-elite riders involved the HIP and $\text{THIGH}_{\text{horiz}}$ angles, and hence the study of elite rider technique should focus on these areas. This is similar to previous research studying walk and trot (Schils *et al.,* 1993) where hip angle was found to be a useful indicator of rider ability when comparing novice, intermediate and experienced riders. Elite riders make more changes to their position within the intermediate (non-jumping) stride than non-elite riders suggesting earlier adaptation of their position for take-off over the next element. Assessment and training of riders should incorporate repetitive jumping efforts to simulate competition demands in terms of the riders' ability to recover quickly on landing in order to prepare for subsequent fences.

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